PATENT ABSTRACTS OF JAPAN

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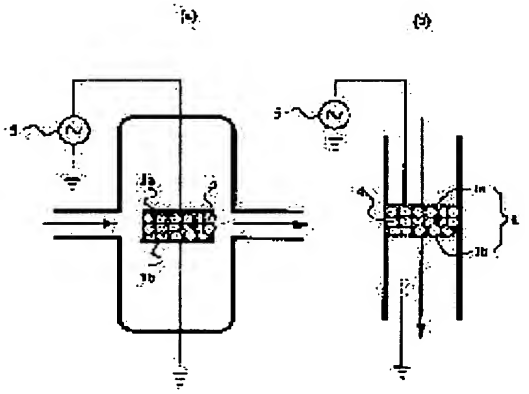
(54) ATMOSPHERIC PLASMA GENERATOR AND ATMOSPHERIC PLASMA GENERATION METHOD USING THE GENERATOR

(57)Abstract:
PURPOSE: To provide an atmospheric plasma generator as well as an atmospheric plasma generation method, having the capability of generating a homogeneous glow discharge under the application of extremely small power even when such gases as air, nitrogen and oxygen are used, and ensuring high energy efficiency as well as high reaction efficiency.
CONSTITUTION: This atmospheric plasma generator has an electrode pair 1 formed out of an electrode 1a connected to an AC power supply 5 and an earth electrode 1b, and AC electrical field is applied across the pair 1 in the presence of gases to generate a glow discharge plasma under the atmospheric pressure. Regarding the generator so formed, the gap of the electrode pair 1 is filled with particle type materials 4 made of a conductor covered with an insulator all around. In this case, the conductor 4 is metal and the insulator is an inorganic dielectric substance. Also, the electrode pair 1 is a metallic net. Furthermore, AC electrical field is applied across the pair 1 in the presence of gases, using the generator, thereby generating a glow discharge plasma under the atmospheric pressure. Also, the gases are mainly composed of the air.



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* NOTICES *

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CLAIMS

[Claim(s)]
[Claim 1] AC power supply (electrode pair (1 which consists of the electrode (1a) connected with 5) and an earth electrode (1b)) is prepared. Under existence of gas In the atmospheric pressure plasma generator which impresses alternating current electric field between said electrode pair (1), and is made to generate the glow discharge plasma under atmospheric pressure The atmospheric pressure plasma generator characterized by being filled up with the granule (4) which covered and formed the insulator (3) all over the conductor (2) between said electrode pair (1).
[Claim 2] The atmospheric pressure plasma generator according to claim 1 characterized by for said conductor (2) being a metal and an insulator (3) being an inorganic dielectric.
[Claim 3] The atmospheric pressure plasma generator according to claim 1 or 2 characterized by said electrode pair (1) being a metal network.
[Claim 4] The atmospheric pressure plasma generating approach characterized by impressing alternating current electric field between said electrode pair (1), and generating the glow discharge plasma under atmospheric pressure under existence of gas using an atmospheric pressure plasma plasma generator according to claim 1 to 3.
[Claim 5] The atmospheric pressure plasma generating approach according to claim 4 characterized by said gas using air as a principal component.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the atmospheric pressure plasma generating approach using the atmospheric pressure plasma generator which can be made to generate the glow discharge stabilized also in air under atmospheric pressure, and its equipment.
[0002]
[Description of the Prior Art] Conventionally, many methods of generating discharge under atmospheric pressure are developed. For example, corona treatment equipment, the ozonizer by silent discharge and creeping discharge, etc. are mentioned. If the sharp discharge electrode and a smooth electrode are opposed and direct-current high tension is applied, gaseous local dielectric breakdown will happen, and corona discharge will be generated when a gas plasma-izes. This is a streamer-like and is in the condition in which the part with very high current density and the part which discharge has not produced were intermingled in the gas. Moreover, if an electrode is formed in an inorganic substance front face and the interior, such as a ceramic, and alternating current electric field are impressed, discharge occurs on a ceramic front face, and creeping discharge is very partial discharge. Although the method of generating the glow discharge which is uniform discharge under atmospheric pressure was also developed in recent years as indicated by JP,63-50478,A, there was a fault that expensive gas, such as helium and an argon, was required. Moreover, there was a method of generating glow discharge, such as air and nitrogen, by the device of an electrode as indicated by JP,5-155605,A or JP,6-119995,A, and discharge space was very small and there was a problem also in stabilization of discharge. Moreover, although the method of generating strong partial discharge by filling up wire gauze-like inter-electrode with a dielectric ceramic, and impressing alternating current electric field was also reported, there was a problem of needing very high applied voltage, for the need of being filled up with an inorganic substance.
[0003]
[Problem(s) to be Solved by the Invention] Even if it uses gas, such as air, and nitrogen, oxygen, the place which this invention was made in view of the aforementioned data, and is make into the object can generate homogeneous glow discharge with very small impression power, and is to offer the atmospheric pressure plasma generating approach using the atmospheric pressure plasma generator excellent in energy efficiency and reaction effectiveness, and its equipment.
[0004]
[Means for Solving the Problem] The atmospheric pressure plasma generator concerning claim 1 of this invention 1 is prepared. the electrode pair which consists of electrode 1a connected with AC power supply 5, and earth electrode 1b -- under existence of gas It is characterized by impressing alternating current electric field between said electrode pair 1, and being filled up with the granule 4 which covered and formed the insulator 3 all over the conductor 2 between said electrode pair 1 in the atmospheric pressure plasma generator made to generate the glow discharge plasma under atmospheric pressure.
[0005] The atmospheric pressure plasma generator concerning claim 2 of this invention is characterized by for said conductor 2 being a metal and an insulator 3 being an inorganic dielectric.
[0006] The atmospheric pressure plasma generator concerning claim 3 of this invention is characterized by said electrode pair 1 being a metal network.
[0007] The atmospheric pressure plasma generating approach concerning claim 4 of this invention is characterized by impressing alternating current electric field between said electrode pair 1, and generating the

glow discharge plasma under [redacted]ospheric pressure under existence of ga[redacted]ng an atmospheric pressure plasma plasma generator according to claim 1 to 3.
[0008] The atmospheric pressure plasma generating approach concerning claim 5 of this invention is characterized by said gas using air as a principal component.
[0009]
[Function] The atmospheric pressure plasma generator concerning claim 1 of this invention 1 is prepared. the electrode pair which consists of electrode 1a connected with AC power supply 5, and earth electrode 1b -- under existence of gas Since it is filled up with the granule 4 which covered and formed the insulator 3 all over the conductor 2 between said electrode pair 1 in the atmospheric pressure plasma generator which impresses alternating current electric field between said electrode pair 1, and is made to generate the glow discharge plasma under atmospheric pressure An electrode with the small conductor 2 in a granule 4 is constituted, and an insulator 3 constitutes the dielectric barrier, and gas plasma-izes by the so-called dielectric barrier discharge in the gap of a granule 4 and a granule 4. Since the gap of this granule 4 is small, even if it is gas with the large breakdown voltage of oxygen, nitrogen, etc., with very small impression power, homogeneous glow discharge can be generated and-izing can be carried out [plasma].
[0010] Since said conductor 2 is a metal and an insulator 3 is an inorganic dielectric, the atmospheric pressure plasma generator concerning claim 2 of this invention is excellent in endurance and thermal resistance.
[0011] since said electrode pair 1 is a metal network as for the atmospheric pressure plasma generator concerning claim 3 of this invention -- gas -- an electrode pair -- 1 can be passed.
[0012] Since the atmospheric pressure plasma generating approach concerning claim 4 of this invention impresses alternating current electric field between said electrode pair 1 under existence of gas and generates the glow discharge plasma under atmospheric pressure using an atmospheric pressure plasma plasma generator according to claim 1 to 3, gas plasma-izes it in the gap of a granule 4 and a granule 4..
[0013] Since said gas uses air as a principal component and ozone is generated, when the impurity gas of a minute amount exists in air, as for the atmospheric pressure plasma generating approach concerning claim 5 of this invention, this impurity gas is decomposed.
[0014]
[Example] This invention is explained based on the drawing concerning an example below.
[0015] Drawing 1 (a) and drawing 1 (b) are the schematic diagrams of one example of the atmospheric pressure plasma generator concerning this invention.
[0016] the electrode pair which consists of electrode 1a connected with AC power supply 5, and earth electrode 1b as the atmospheric pressure plasma generator concerning this invention is shown in drawing 1 (a) and drawing 1 (b) -- 1 is prepared, alternating current electric field are impressed between said electrode pair 1 under existence of gas, and the glow discharge plasma is generated under atmospheric pressure, for example, various kinds of surface treatment, ozone generating, flue gas treatment, etc. can be performed. It is filled up with the granule 4 which covered and formed the insulator 3 all over the conductor 2 between said electrode pair 1 as shown in drawing 2 (a). As said conductor 2, although a metal or carbon, such as stainless steel, copper, brass, aluminum, iron, a tungsten, nickel, and a tantalum, etc. is mentioned, when you need endurance and thermal resistance, the metal is excellent. moreover -- as an insulator 3 -- the organic substance, such as nylon, polyester, polyimide, Teflon, Pori Sall John, and epoxy, or an inorganic substance -- although all can be used, when you need endurance and thermal resistance, inorganic dielectrics, such as glass, ceramics, and an enamel, are excellent. Although not limited especially as an approach of covering an insulator 3 all over a conductor 2, coating of a spraying process and a sol gel solution and heat hardening, and when using a refractory metal, the calcinating method etc. is mentioned further, for example. Moreover, in covering an organic material as an insulator 3 all over a conductor 2, it covers organic materials, such as resin, with heat hardening around a conductor 2. Between a conductor 2 and an insulator 3, it is desirable to make it stick that there is no gap as possible in order to gather discharge effectiveness. As said granule 4 is shown in drawing 2 (b), two or more conductors 2 may exist in the interior of an insulator 3. That is, the conductor 2 may be distributed in the insulator 3. As magnitude of a granule 4, although it changes with applications, generally it is dozens of mm order from 0.1 mm. a configuration -- a globular shape, corniform, or an indeterminate configuration -- any are sufficient and it is not limited. Moreover, coat thickness changes with a granule and coat approaches.

[0017] the electrode pair which consists of electrode 1a and earth electrode 1b -- the ingredient of 1 has desirable metaled plate or metaled metal network. In the case of a metal network, it changes with classes of gas, but what consisted of metal thin lines of an about 0.01-0.5mm size is desirable. As construction material of this metal network, stainless steel, copper, brass, aluminum, iron, a tungsten, nickel, a tantalum, etc. are illustrated. as the weave of this metal network -- plain weave, twill, and a tatami -- various kinds of approaches, such as textile, are employable.

[0018] The homogeneous glow discharge plasma occurs between granules 4 under atmospheric pressure by installing said electrode 1a and earth electrode 1b in abbreviation parallel, being filled up with said granule 4, and impressing alternating current electric field between said electrode pair 1 under existence of gas. The device of this glow discharge plasma generating is considered as follows. That is, an electrode with the small conductor 2 in a granule 4 is constituted, and an insulator 3 constitutes the dielectric barrier, and gas plasma-izes by the so-called dielectric barrier discharge in granule 4 gap. Since the gap of a granule 4 is small, even if it is gas with the large breakdown voltage of oxygen, nitrogen, etc., it can be made to generate with very small impression power, and-izing of the homogeneous glow discharge can be carried out [plasma]. Therefore, it can discharge also with air. Moreover, the gas with the small breakdown voltage of hydrogen, an argon, helium, etc. can carry out [plasma]-izing with a natural thing. Although an electrode spacing and electrode size can be taken to arbitration since said granule 4 constitutes the small dielectric barrier as mentioned above, discharge sustaining voltage becomes high according to size.

[0019] An alternating current frequency required for discharge can be used in the range of a RF (MHz) from 50Hz commercial frequency. This approach can be used for various kinds of processings. For example, as surface preparation, if a processed material is installed in the lower stream of a river of plasma space, it will remain without the gas radical-ized in the plasma still disappearing, and it will act on a processed material front face, and the so-called low-temperature plasma treatment can be performed. Moreover, ozone is generated when gas is air, and air passes through discharge space. According to the atmospheric pressure plasma generating approach concerning this invention, since discharge space is large, compared with a conventional method, generating effectiveness becomes large. Moreover, these offensive odor components can be decomposed and defanged by passing the gas containing offensive odor components, such as ammonia and a hydrogen sulfide. Since this has uniform discharge, compared with a conventional method, decomposition effectiveness becomes high.

[0020] An example of the approach of using the atmospheric pressure plasma generator of this invention for below, and generating the atmospheric pressure plasma is given.

[0021] (Example 1) the electrode pair of the parallel plate which consists of electrode 1a made from stainless steel connected with AC power supply 5, and earth electrode 1b in the atmospheric pressure plasma generator shown in drawing 1 (a) -- 1 was installed at intervals of 3cm. Said space of electrode pair 1 was filled up with the granule 4 which formed the alumina in the surroundings of a copper grain object with a diameter of 3mm by the thickness of 100 micrometers by thermal spraying. The electrical potential difference of 60Hz and 5kV was impressed to these ends of electrode pair 1, dry air (79% of nitrogen, 21% of oxygen) was circulated by the 10l. flow rate for /to said space, and the plasma was generated. The high density polyethylene film was installed in the lower stream of a river (not shown) of plasma space for 1 minute. When lamination of the high density polyethylene film which performed this plasma treatment was carried out to the aluminum plate through the epoxy adhesive and bond strength (shearing stress trial) was measured, to the bond strength of a plasma unsettled article being 500psi(s), the bond strength of a plasma treatment article is 2800psi, and bond strength of a plasma treatment article improved greatly compared with the plasma unsettled article.

[0022] (Example 2) the electrode pair which consists the stainless steel wire gauze of 325 meshes of electrode 1a and earth electrode 1b in the atmospheric pressure plasma generator shown in drawing 1 (b) by 0.035mm of wire sizes connected with AC power supply 5 -- it used as 1, dry air (79% of nitrogen, 21% of oxygen) was fed, the electrical potential difference of 60Hz and 5kV was impressed, and the plasma was generated. The ozone generation energy efficiency at this time was investigated. As a result of measuring a current potential property with an oscilloscope, creating a Lissajous's figure and investigating spark discharge energy, it has checked that effectiveness improved about 35% compared with the generation energy efficiency of the ozone by the conventional silent discharge.

[0023] (Example 3) In the example 2, the dry air (79% of nitrogen, 21% of oxygen) containing 100 ppm of

ammonia gas was circulated [redacted]e 10l. flow rate for /to plasma space. T[redacted]ectrical potential difference of 60Hz and 5kV was impressed to this, and the plasma was generated. As a result of a gas detector's analyzing the concentration of outlet gas, ammonia concentration decreased to 5 ppm.

[0024] In addition, in the example 1 thru/or the example 3, it was not that in which the granule 4 covered and formed the insulator 3 all over the conductor 2, and when the granule 4 formed only with the insulator 3 was used, even if it impressed the electrical potential difference of 60Hz and 15kV, of course in 60Hz and 5kV, the plasma did not occur.

[0025]

[Effect of the Invention] Since according to the atmospheric pressure plasma generator concerning claim 1 of this invention homogeneous glow discharge can be generated with very small impression power even if it is gas with large breakdown voltage, such as oxygen, nitrogen, or air, the glow discharge stabilized also in air can be generated under atmospheric pressure, and the atmospheric pressure plasma excellent in energy efficiency and reaction effectiveness can be generated.

[0026] Since according to the atmospheric pressure plasma generator concerning claim 2 of this invention said conductor 2 is a metal and an insulator 3 is an inorganic dielectric, in addition to the above, it excels in endurance and thermal resistance.

[0027] since atmospheric pressure plasma generator **** concerning claim 3 of this invention and said electrode pair 1 are metal networks -- gas -- an electrode pair -- since 1 can be passed, it excels in energy efficiency and reaction effectiveness further.

[0028] According to the atmospheric pressure plasma generating approach concerning claim 4 of this invention, an atmospheric pressure plasma plasma generator according to claim 1 to 3 is used. Under existence of gas Since alternating current electric field are impressed between said electrode pair 1 and the glow discharge plasma is generated under atmospheric pressure Since gas plasma-izes in the gap of a granule 4 and a granule 4 and homogeneous glow discharge can be generated with very small impression power, the glow discharge stabilized also in air can be generated under atmospheric pressure, and it excels in energy efficiency and reaction effectiveness.

[0029] Since ozone is generated according to the atmospheric pressure plasma generating approach concerning claim 5 of this invention, the generation energy efficiency of ozone improves and the impurity gas in air is decomposed, pollutants, such as exhaust gas, can be purified.

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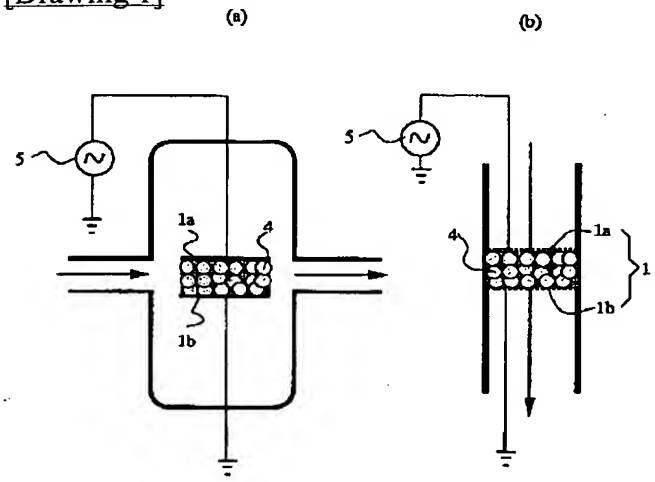
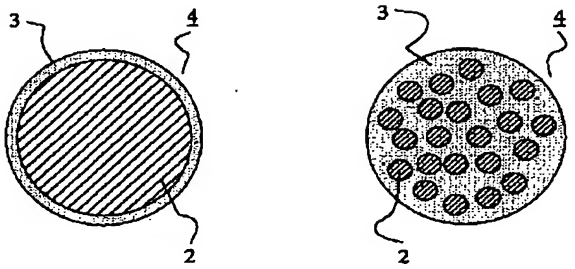
DRAWINGS

[Drawing 1]



[Drawing 2]



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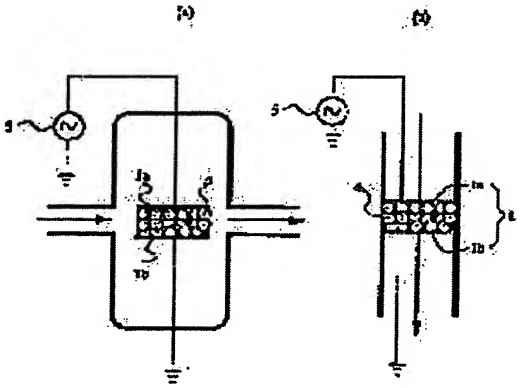
CONSTITUTION: This atmospheric plasma generator has an electrode pair 1 formed out of an electrode 1a connected to an AC power supply 5 and an earth electrode 1b, and AC electrical field is applied across the pair 1 in the presence of gases to generate a glow discharge plasma under the atmospheric pressure. Regarding the generator so formed, the gap of the electrode pair 1 is filled with particle type materials 4 made of a conductor covered with an insulator all around. In this case, the conductor 4 is metal and the insulator is an inorganic dielectric substance. Also, the electrode pair 1 is a metallic net. Furthermore, AC electrical field is applied across the pair 1 in the presence of gases, using the generator, thereby generating a glow discharge plasma under the atmospheric pressure. Also, the gases are mainly composed of the air.



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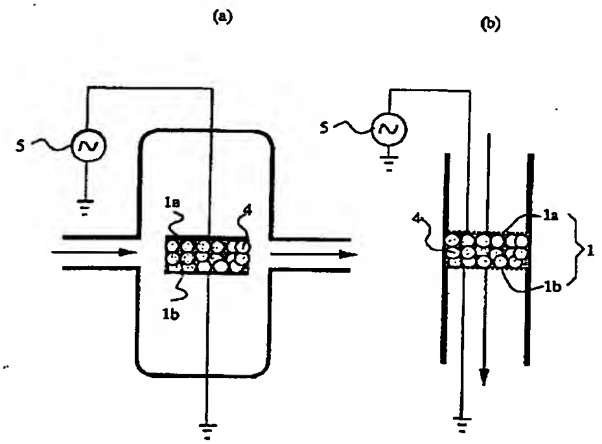
(54)【発明の名称】　大気圧プラズマ発生装置及びその装置を用いた大気圧プラズマ発生方法

(57)【要約】

【目的】　空気や窒素、酸素等のガスを使用しても、均質なグロー放電を極めて小さい印加電力で発生させることができ、エネルギー効率、反応効率に優れた大気圧プラズマ発生装置及びその装置を用いた大気圧プラズマ発生方法を提供する。

【構成】　交流電源５と接続される電極１ａと接地電極１ｂとから成る電極対１を設けて、ガスの存在下で、前記電極対１間に交流電界を印加して、大気圧下でグロー放電プラズマを発生させる大気圧プラズマ発生装置において、前記電極対１間に、導電体の全面に絶縁体を被覆して形成した粒状体４を充填する。前記導電体が金属であり、絶縁体が無機誘電体である。前記電極対１が金属網である。前記大気圧プラズマプラズマ発生装置を用いて、ガスの存在下で、前記電極対１間に交流電界を印加して、大気圧下でグロー放電プラズマを発生させる。前記ガスが空気を主成分とする。



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【特許請求の範囲】

【請求項１】　交流電源（５）と接続される電極（１ａ）と接地電極（１ｂ）とから成る電極対（１）を設けて、ガスの存在下で、前記電極対（１）間に交流電界を印加して、大気圧下でグロー放電プラズマを発生させる大気圧プラズマ発生装置において、前記電極対（１）間に、導電体（２）の全面に絶縁体（３）を被覆して形成した粒状体（４）を充填することを特徴とする大気圧プラズマ発生装置。

【請求項２】　前記導電体（２）が金属であり、絶縁体（３）が無機誘電体であることを特徴とする請求項１記載の大気圧プラズマ発生装置。

【請求項３】　前記電極対（１）が金属網であることを特徴とする請求項１又は請求項２記載の大気圧プラズマ発生装置。

【請求項４】　請求項１乃至請求項３のいずれかに記載の大気圧プラズマプラズマ発生装置を用いて、ガスの存在下で、前記電極対（１）間に交流電界を印加して、大気圧下でグロー放電プラズマを発生させることを特徴とする大気圧プラズマ発生方法。

【請求項５】　前記ガスが空気を主成分とすることを特徴とする請求項４記載の大気圧プラズマ発生方法。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、大気圧下で空気中でも安定したグロー放電を発生させることができる大気圧プラズマ発生装置及びその装置を用いた大気圧プラズマ発生方法に関する。

【０００２】

【従来の技術】従来、大気圧下で放電を発生させる方法は数多く開発されている。例えば、コロナ処理装置や無声放電、沿面放電によるオゾナイザー等が挙げられる。コロナ放電は、尖った放電電極となめらかな電極とを向かい合わせて直流高電圧を加えると、気体の局所的な絶縁破壊が起こり、気体がプラズマ化することによって発生する。これはストリーマ状であり気体中できわめて電流密度の高い部分と放電が生じていない部分とが混在した状態である。また沿面放電は、セラミック等の無機物表面と内部に電極を形成し、交流電界を印加するとセラミック表面に放電が発生するもので、極めて部分的な放電である。特開昭６３－５０４７８号公報に開示されているように、均一な放電であるグロー放電を大気圧下で発生させる方法も近年開発されているが、ヘリウムやアルゴン等の高価なガスが必要であるという欠点があった。また、特開平５－１５５６０５号公報又は特開平６－１１９９９５号公報に開示されているように、電極の工夫により、空気や窒素等のグロー放電を発生させる方法もあるが、放電空間が極めて小さく、また放電の安定化にも問題があった。また、誘電体セラミックを金網状電極間に充填し交流電界を印加することにより強い部分放電を発生する方法も報告されているが、無機物を充填する必要性のため、極めて高い印加電圧を必要とするという問題があった。

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【０００３】

【発明が解決しようとする課題】本発明は前記の事実に鑑みてなされたもので、その目的とするところは、空気や窒素、酸素等のガスを使用しても、均質なグロー放電を極めて小さい印加電力で発生させることができ、エネルギー効率、反応効率に優れた大気圧プラズマ発生装置及びその装置を用いた大気圧プラズマ発生方法を提供することにある。

【０００４】

【課題を解決するための手段】本発明の請求項１に係る大気圧プラズマ発生装置は、交流電源５と接続される電極１ａと接地電極１ｂとから成る電極対１を設けて、ガスの存在下で、前記電極対１間に交流電界を印加して、大気圧下でグロー放電プラズマを発生させる大気圧プラズマ発生装置において、前記電極対１間に、導電体２の全面に絶縁体３を被覆して形成した粒状体４を充填することを特徴とする。

【０００５】本発明の請求項２に係る大気圧プラズマ発生装置は、前記導電体２が金属であり、絶縁体３が無機誘電体であることを特徴とする。

【０００６】本発明の請求項３に係る大気圧プラズマ発生装置は、前記電極対１が金属網であることを特徴とする。

【０００７】本発明の請求項４に係る大気圧プラズマ発生方法は、請求項１乃至請求項３のいずれかに記載の大気圧プラズマプラズマ発生装置を用いて、ガスの存在下で、前記電極対１間に交流電界を印加して、大気圧下でグロー放電プラズマを発生させることを特徴とする。

【０００８】本発明の請求項５に係る大気圧プラズマ発生方法は、前記ガスが空気を主成分とすることを特徴とする。

【０００９】

【作用】本発明の請求項１に係る大気圧プラズマ発生装置は、交流電源５と接続される電極１ａと接地電極１ｂとから成る電極対１を設けて、ガスの存在下で、前記電極対１間に交流電界を印加して、大気圧下でグロー放電プラズマを発生させる大気圧プラズマ発生装置において、前記電極対１間に、導電体２の全面に絶縁体３を被覆して形成した粒状体４を充填するので、粒状体４中の導電体２が小さい電極を構成し、また、絶縁体３が誘電体バリアを構成し、いわゆる誘電体バリア放電により、粒状体４と粒状体４との間隙でガスがプラズマ化する。この粒状体４の間隙が小さいので、酸素や窒素などの放電開始電圧の大きいガスであっても、極めて小さい印加電力で均質なグロー放電を発生させることができ、プラズマ化できる。

【００１０】本発明の請求項２に係る大気圧プラズマ発

生装置は、前記導電体２が金属であり、絶縁体３が無機誘電体であるので、耐久性、耐熱性に優れる。

【００１１】本発明の請求項３に係る大気圧プラズマ発生装置は、前記電極対１が金属網であるので、ガスが電極対１を通過することができる。

【００１２】本発明の請求項４に係る大気圧プラズマ発生方法は、請求項１乃至請求項３のいずれかに記載の大気圧プラズマプラズマ発生装置を用いて、ガスの存在下で、前記電極対１間に交流電界を印加して、大気圧下でグロー放電プラズマを発生させるので、粒状体４と粒状体４との間隙でガスがプラズマ化する。

【００１３】本発明の請求項５に係る大気圧プラズマ発生方法は、前記ガスが空気を主成分とするので、オゾンが生成されるため、空気中に微量の不純物ガスが存在する場合には、この不純物ガスが分解される。

【００１４】

【実施例】以下本発明を実施例に係る図面に基づいて説明する。

【００１５】図１（ａ）及び図１（ｂ）は、本発明に係る大気圧プラズマ発生装置の一実施例の概略図である。

【００１６】本発明に係る大気圧プラズマ発生装置は、図１（ａ）及び図１（ｂ）に示すように、交流電源５と接続される電極１ａと接地電極１ｂとから成る電極対１を設けて、ガスの存在下で、前記電極対１間に交流電界を印加して、大気圧下でグロー放電プラズマを発生させて、例えば、各種の表面処理やオゾン発生、排ガス処理等を行うことができるものである。前記電極対１間に、図２（ａ）に示すように、導電体２の全面に絶縁体３を被覆して形成した粒状体４を充填する。前記導電体２としては、ステンレス、銅、真鍮、アルミニウム、鉄、タングステン、ニッケル、タンタル等の金属又はカーボン等が挙げられるが、耐久性、耐熱性を必要とする場合には、金属が優れている。また、絶縁体３としてはナイロン、ポリエステル、ポリイミド、テフロン、ポリサルフォン、エポキシ等の有機物又は無機物いずれも使用できるが、耐久性、耐熱性を必要とする場合には、ガラス、セラミックス、ほうろう等の無機誘電体が優れている。導電体２の全面に絶縁体３を被覆する方法としては特に限定されないが、例えば、溶射法、ゾルゲル溶液のコーティング及び加熱硬化、さらに、高融点金属を使用する場合には、焼成法等が挙げられる。また、導電体２の全面に絶縁体３として有機材料を被覆する場合には、例えば、加熱硬化により樹脂等の有機材料を導電体２の回りに被覆する。導電体２と絶縁体３との間は出来るだけ間隙なく密着させることが、放電効率を上げるために好ましい。前記粒状体４は、図２（ｂ）に示すように、絶縁体３の内部に導電体２が複数個存在するものであってもよい。すなわち、導電体２が絶縁体３の中に分散されていてもよい。粒状体４の大きさとしては、用途により異なるが、一般的には０．１mmから数十mmのオーダーである。形状は球状、角状又は不定形状いずれでもよく限定されない。また、被覆厚みは粒状体、被覆方法により異なる。

【００１７】電極１ａと接地電極１ｂとから成る電極対１の材料は金属の平板あるいは金属網が好ましい。金属網の場合、ガスの種類により異なるが、０．０１～０．５mm程度の太さの金属細線より構成されたものが好ましい。この金属網の材質としては、ステンレス、銅、真鍮、アルミニウム、鉄、タングステン、ニッケル、タンタル等が例示される。この金属網の織り方としては、例えば、平織、綾織、畳織り等の各種の方法を採用することができる。

【００１８】前記電極１ａと接地電極１ｂとを略平行に設置し、前記粒状体４を充填して、ガスの存在下で、前記電極対１間に交流電界を印加することにより、大気圧下で、粒状体４間に均質なグロー放電プラズマが発生する。このグロー放電プラズマ発生の機構は次のように考えられる。すなわち、粒状体４中の導電体２が小さい電極を構成し、また、絶縁体３が誘電体バリアを構成し、いわゆる誘電体バリア放電により粒状体４間隙でガスがプラズマ化する。粒状体４の間隙が小さいので、酸素や窒素などの放電開始電圧の大きいガスであっても、均質なグロー放電を極めて小さい印加電力で発生させることができ、プラズマ化できる。従って、空気でも放電できる。また水素、アルゴン、ヘリウムなどの放電開始電圧の小さいガスは当然のことながらプラズマ化できる。前述のように前記粒状体４が小さい誘電体バリアを構成するために、電極間隔及び電極サイズは任意に取ることが出来るが、放電維持電圧はサイズに応じて高くなる。

【００１９】放電に必要な交流周波数は５０Ｈｚ商用周波数から高周波（ＭＨｚ）の範囲で使用できる。本方法を各種の処理に利用することが出来る。例えば、表面処理として、プラズマ空間の下流に被処理物を設置すると、プラズマ中でラジカル化したガスがまだ消滅しないで残存し被処理物表面に作用して、いわゆる低温プラズマ処理が出来る。また、ガスが空気の場合には、空気が放電空間を通過することによって、オゾンが生成される。本発明に係る大気圧プラズマ発生方法によると、放電空間が大きいため、従来法と比べて発生効率が大きくなる。また、アンモニアや硫化水素などの悪臭成分を含んだガスを通過させることにより、これらの悪臭成分を分解し、無害化出来る。これは放電が均一であるため、従来法と比べて分解効率が高くなる。

【００２０】以下に本発明の大気圧プラズマ発生装置を用いて大気圧プラズマを発生する方法の一例を挙げる。

【００２１】（実施例１）図１（ａ）に示す大気圧プラズマ発生装置において、交流電源５と接続されるステンレス製の電極１ａと接地電極１ｂとから成る平行平板の電極対１を３ｃmの間隔で設置した。直径３mmの銅粒体のまわりにアルミナを溶射により１００μmの厚みで

形成した粒状体４を前記電極対１の空間に充填した。この電極対１の両端に６０Ｈｚ、５ＫＶの電圧を印加し乾燥空気（窒素７９％、酸素２１％）を前記空間に１０リットル／分の流量で流通させてプラズマを発生させた。プラズマ空間の下流（図示せず）に高密度ポリエチレンフィルムを１分間設置した。このプラズマ処理を施した高密度ポリエチレンフィルムをエポキシ接着剤を介してアルミニウム板と張り合わせし、接着強度（剪断応力試験）を測定したところ、プラズマ未処理品の接着強度が５００ｐｓｉであるのに対して、プラズマ処理品の接着強度は、２８００ｐｓｉであり、プラズマ未処理品と比べてプラズマ処理品は、接着強度が大きく向上した。

【００２２】（実施例２）図１（ｂ）に示す大気圧プラズマ発生装置において、交流電源５と接続される線径０．０３５ｍｍで３２５メッシュのステンレス金網を電極１ａと接地電極１ｂとから成る電極対１として用い、乾燥空気（窒素７９％、酸素２１％）を送入し、６０Ｈｚ、５ＫＶの電圧を印加してプラズマを発生させた。このときのオゾン生成エネルギー効率を調べた。オシロスコープで電流電圧特性を測定し、リサジュー図形を作成して放電エネルギーを調べた結果、従来の無声放電によるオゾンの生成エネルギー効率に比べて効率が３５％程度向上することが確認できた。

【００２３】（実施例３）実施例２において、アンモニアガスを１００ｐｐｍ含有した乾燥空気（窒素７９％、酸素２１％）をプラズマ空間に１０リットル／分の流量で流通させた。これに６０Ｈｚ、５ＫＶの電圧を印加してプラズマを発生させた。出口ガスの濃度をガス検知管で分析した結果、アンモニア濃度が５ｐｐｍまで減少した。

【００２４】なお、実施例１乃至実施例３において、粒状体４が導電体２の全面に絶縁体３を被覆して形成したものではなく、絶縁体３のみで形成した粒状体４を用いた場合には、６０Ｈｚ、５ＫＶではもちろんのこと、６０Ｈｚ、１５ＫＶの電圧を印加しても、プラズマが発生しなかった。

【００２５】

【発明の効果】本発明の請求項１に係る大気圧プラズマ発生装置によると、酸素、窒素又は空気等の放電開始電圧の大きいガスであっても、極めて小さい印加電力で均質なグロー放電を発生させることができるので、大気圧下で空気中でも安定したグロー放電を発生させることができ、エネルギー効率、反応効率に優れた大気圧プラズマを発生させることができる。

【００２６】本発明の請求項２に係る大気圧プラズマ発生装置によると、前記導電体２が金属であり、絶縁体３が無機誘電体であるので、前記に加えて、耐久性、耐熱性に優れる。

【００２７】本発明の請求項３に係る大気圧プラズマ発生装置よると、前記電極対１が金属網であるので、ガスが電極対１を通過することができるので、さらに、エネルギー効率、反応効率に優れる。

【００２８】本発明の請求項４に係る大気圧プラズマ発生方法によると、請求項１乃至請求項３のいずれかに記載の大気圧プラズマプラズマ発生装置を用いて、ガスの存在下で、前記電極対１間に交流電界を印加して、大気圧下でグロー放電プラズマを発生させるので、粒状体４と粒状体４との間隙でガスがプラズマ化するので、極めて小さい印加電力で均質なグロー放電を発生させることができるので、大気圧下で空気中でも安定したグロー放電を発生させることができ、エネルギー効率、反応効率に優れる。

【００２９】本発明の請求項５に係る大気圧プラズマ発生方法によると、オゾンが生成されるので、オゾンの生成エネルギー効率が向上し、空気中の不純物ガスが分解されるため、排ガス等の汚染物質を浄化できる。

【図面の簡単な説明】

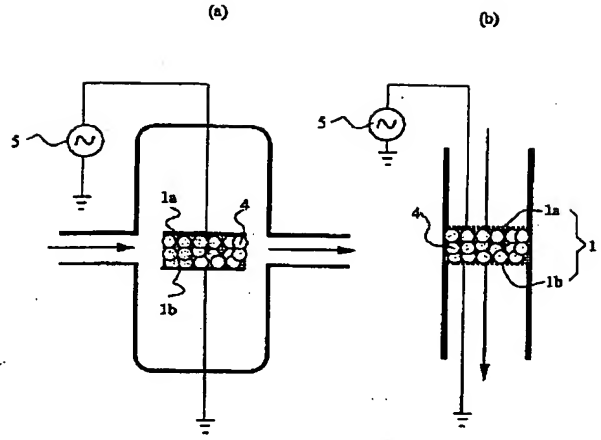
【図１】本発明の実施例に係る大気圧プラズマ発生装置の概略説明図であり、（ａ）は電極対の材料が金属の平板である大気圧プラズマ発生装置の要部断面図、（ｂ）は電極対の材料が金属網である大気圧プラズマ発生装置の要部断面図である。

【図２】本発明の実施例に係る大気圧プラズマ発生装置に用いる粒状体の断面図であり、（ａ）は導電体の全面に絶縁体を被覆して形成した粒状体の断面図、（ｂ）は絶縁体の内部に導電体が複数個存在する粒状体の断面図である。

【符号の説明】

１	電極対
１ａ	電極
１ｂ	接地電極
２	導電体
３	絶縁体
４	粒状体
５	交流電源

【図１】



【図２】